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FINAL REPORT

GRANT #: N00014-02-1-0460

PRINCIPAL INVESTIGATOR: Aaron M Thode

INSTITUTION: Marine Physical Laboratory, Scripps Institution of Oceanography

GRANT TITLE: Supplemental Equipment Request for Advanced Marine Mammal Acoustic Localization

AWARD PERIOD: 18 February 2003 - 30 June 2004

OBJECTIVE: This award is supplemental support for a larger three-year $300K award from ONR Ocean Acoustics(N00014-03-1-0215). The overall project goal is to modify flash-memory recorders, originally developed for marine mammal acoustic tags, into modular, portable, and rugged array systems that can be deployed in multiple configurations from inexpensive deployment platforms (i.e. boats), and even from autonomous underwater vehicles (AUVs).

These arrays have been used to test various acoustic localization techniques on several marine mammal species that produce vocalizations in the 10-10000 Hz range, with an emphasis on matched-field processing (MFP) methods. MFP methods have the potential of permitting 3-D passive acoustic tracking of sound sources using a collection of sensors deployed at one location, instead of being deployed over multiple locations.

APPROACH: The equipment support was used to help fund the construction of five of a total of eight modified acoustic "bioprobes" built by Bill Burgess of Greeneridge Sciences, Inc. The original probe design had 255 MB of memory and a pressure and temperature sensor encased in epoxy, with a small lithium battery that limited its effective recording life. For this project the electronics were instead inserted into acrylic pressure cases to permit rechargeable AAA batteries to be used (thus providing more power), to allow different hydrophones to be substituted, and to permit additional flash memory chips to be swapped in the field to avoid having to download data before redeploying the instrument. In addition an accelerometer to measure instrument tilt was incorporated. In both designs all data is transferred from flash memory via infrared transfer using a serial port protocol through the transparent housing.

These autonomous recorders record acoustic data independently, eliminating the need for wires and strong mechanical cables, but sacrificing the ability to monitor the signals in real-time. The data across multiple

instruments are time-synchronized by using a combination of active acoustic pulses, ambient wind-driven ocean noise, and even marine mammal vocalizations themselves, using so-called "focalization" techniques. The auxiliary pressure, temperature, and tilt data are used to determine the relative position of the elements to aid in the time synchronization.

ACCOMPLISHMENTS:

The system was deployed as a 75 ft long bottom-mounted vertical array using a small boat in Oct. 2003, off the Australian coast. The data collected were used to perform MFP and geoacoustic inversions on humpback whale song in Australia, in collaboration with the Humpback Acoustic Research Consortium (HARC), lead by Doug Cato, Mike Noad, Dale Stokes, and Grant Deane. Thus, it has been demonstrated that marine mammal vocalizations can be used to time-align the internal clocks of the acoustic recorders, using the inversion software package SAGA. Data from blue whales were collected in Sept. 2003.

The autonomous recorders have also been deployed as a large-aperture towed array, and a large-aperture vertical array as part of sperm whale tracking studies, supported by the Minerals Management Service (MMS) and the North Pacific Research Board (NPRB). Data collected by these instruments have lead to funded projects with specialized acoustic hardware, and a peer-reviewed publication. The NPRB work has also shown that commercial fishing gear can be converted into large-aperture acoustic arrays for sperm whale tracking.

The acoustic recorders were also used to instrument a new underwater glider design for field tests in April, 2004. The acoustic flow noise characteristics, pitch, and roll of the vehicle were measured by the recorders, and the recovered data were used to redistribute the buoyancy along the hull to permit stable glide trajectories. This work thus enabled the first field work under ONR grant N00014-04-1-0558, "Flying Wing Underwater Glider for Persistent Surveillance Missions".

CONCLUSIONS: By attaching these recorders to ropes, fishing gear, and even autonomous underwater vehicles (AUVs), I have demonstrated how the acoustic data on marine mammal acoustic tags can be time-synchronized using a variety of methods, creating an effective acoustic array. A variety of complex array geometries can now be deployed quickly and inexpensively, using gear that can be carried in hand luggage onto a commercial aircraft.

SIGNIFICANCE: Since mid-2003, when the equipment first became available to me, the modular array system, or 'insta-array', has been successfully deployed as a large-aperture towed array, a bottom-anchored vertical array, a free-floating large-aperture vertical array, and a linear array mounted inside a new type of AUV. The deployments, in turn, have enabled advanced localization and inversion studies of humpback whales in Australia, have permitted observations of how sperm whales interact with fishing gear, and have demonstrated how towed arrays from seismic vessels can obtain three-dimensional dive profiles of nearby sperm whales. One deployment, I believe, even helped initiate a process that helped a new AUV program become funded. The continued development of the insta-array concept, and its integration into other "distributed sensors and systems" being applied elsewhere, represent a fundamental advancement in the ability of acoustic oceanographers to go to sea.

PATENT INFORMATION: A technology transfer form has been submitted to the University of California Technology Transfer Office, discussing a method where ambient ocean noise can be used to time-synchronize autonomous acoustic recorders.

AWARD INFORMATION: ONR Entry-Level Ocean Acoustic Faculty Award (2002)

RELEVENT PUBLICATIONS AND ABSTRACTS TO DATE:

1. Thode, A (2004) Tracking sperm whale (Physeter macrocephalus) dive profiles using a towed passive acoustic array. J. Acous. Soc. Am., in press.
2. Thode, A.M., Gerstoft, P., Noad, M., Stokes, D., Cato, D. (2004) Matched-field processing and geoacoustic inversion of humpback whale song off eastern Australia, abstract to be presented at the 2nd Workshop for Acoustic Inversion Methods and Experiments for Assessment of the Shallow Water Environment, Ischia, Italy, June 2004.
3. Thode, A. (2003) Development and testing of a portable matched-field processing system for 3D localization of low-frequency marine mammal sounds, abstract presented at ECOUS 2003, 14 May 2003, San Antonio Texas.